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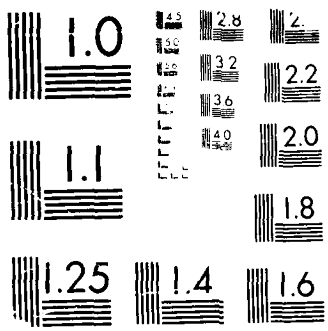

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Effects of Atmospheric Model Layering on LOWTRAN 6 Calculations of 8- to 12-μm Near-Horizon Sky Radiances

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Measurements of 8- to 12-micrometer near-horizon sky radiances and meteorological parameters over the ocean near San Diego, California were used to evaluate the sky radiance algorithm of LOWTRAN 6. Discrepancies in measured and calculated sky radiances previously attributed to the neglect of multiple scattering effects of aerosols can be overcome by introducing additional low-level layers in the calculations of LOWTRAN 6. A comparison between radiance calculations using the single scattering, additive-layer approach and those using a multiple scattering version of LOWTRAN 6 raises questions about the applicability of the multiple scattering approach in the far infrared region.

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INTRODUCTION

In earlier work, Ben-Shalom et al. (1980) presented measurements of infrared spectral (3 to 13 μm) sky radiances which agreed well with LOWTRAN 4 (Selby et al., 1978) calculations close to the zenith using radiosonde data as inputs to the atmospheric model. However, a discrepancy was found at a zenith angle of 90° where the LOWTRAN-calculated radiances were approximately 30 percent lower than the measured values. While the authors did not state which LOWTRAN aerosol model was used in the calculations, they attributed the discrepancy to the neglect of multiple scattering effects by aerosols. Whether aerosols should have been considered at all is suspect since the low-angle measured radiances agree well with those determined from Planck's blackbody equation with the ambient temperature for clear air. Nevertheless, Ben-Shalom et al. (1980) proposed a zero-order modification to LOWTRAN which allows aerosol scattering to be included as a source of radiance. A question still remains as to whether the zero-order modification is the solution for accurate understanding of the infrared radiance of the sky at low elevations. Using measurements of near-horizon sky radiances and radiosonde measurements of meteorological parameters, Hughes, Schade, and Hitney (1986) have shown that the proposed conservative scattering modifications grossly overestimate the calculated sky radiances using the Navy Aerosol Model of LOWTRAN 6 (Kneizys et al., 1983). At a zenith angle of 90°, the radiances calculated with the modification were the same with and without aerosols. As the elevation angle above the horizon was increased, the calculated radiances increased as the visibility decreased.

In this report, measurements of 8- to 12-μm near-horizon sky radiances and meteorological parameters over the ocean near San Diego, California, are used to evaluate the sky radiance algorithm of LOWTRAN 6.

MEASUREMENTS AND LOWTRAN CALCULATIONS

The infrared (8 to 12 μm) sky radiances for this investigation were obtained with a calibrated thermal imaging system (AGA THERMOVISION, Model 780) using a 2.95° field-of-view (FOV) lens with an instantaneous field of view (IFOV) of 0.9 mrad. The response of the system was determined by placing a blackbody of known temperature (±0.1°C for temperatures <50°C) at the minimum focusing distance of 300 cm in front of the lens aperture. At that distance, the blackbody (10 cm diameter) subtended an angle of 33 mr which more than filled the IFOV. The digitized video signal transfer function of the system then allowed the blackbody temperature to be reproduced to within ±0.2°C The video output of the scanner is digitized and processed on a microcomputer to allow the temperature of selected pixels of the scene to be displayed. For these measurements the scanner was located on the Point Loma peninsula in San Diego and directed due west over the ocean from an altitude of 33 m so that approximately one-half of the FOV was above the horizon.

Simultaneously with the radiance measurements, meteorological parameters were measured by a dropsonde released from an aircraft approximately 8 km off the coast of Point Loma. The radiosonde system employed was the VAISALA model RS80. The surface wind speeds and directions were recorded on shore at the sensor site.

Figure 1 shows measured values of sky radiance versus zenith angle together with LOWTRAN 6 calculations using the Navy Maritime Aerosol Model. These data were obtained on 9 December 1986 for a low wind speed condition. The measured and calculated radiances agree well except in a narrow region around the zenith angle of 90° where the LOWTRAN 6 calculations show a dip. The dip is not restricted to this particular aerosol model and is not present in the molecular cases. This is illustrated in figure 2 where the calculations are made without including aerosols with the Urban Aerosol Model for differing visibilities. In this example, the calculations show a strong dip around zenith angle of 90° for the poorer visibilities (high aerosol content). Instead of increasing towards the horizon as in the molecular case, the radiances calculated with aerosols tend to decrease.

Hughes (1987) showed that the calculated radiances at zenith angles near 90° were sensitive to the number of radiosonde levels included in the calculations below 1 km. The dip feature is caused by the numerical evaluation of the radiative transfer equation for large optical paths with relatively coarse atmospheric layering. In LOWTRAN 6, the contribution of the *ith* layer to the radiance reaching the sensor on the ground is given as

$$I(\nu) = [\tau_a(i) - \tau_a(i+1)] \times B(\nu, T) \times \{[\tau_s(i) + \tau_s(i+1)]/2\} \quad (1)$$

where ν is the wave number and T is layer temperature. $B(\nu,T)$ is Planck's function, and τ_a and τ_s are the absorption and scattering transmittances, respectively. In equation 1, the absorption transmittance difference determines the amount of radiance emitted by the *ith* layer. The averaged scattering transmittance from the middle of the layer to the sensor attenuates the emitted radiance. As the zenith angle is increased, the amount of radiance emitted by the layer increases. Because of the longer path within the atmosphere, the scattering transmittance to a specific layer decreases. Usually the lower atmospheric layers are also at higher temperatures such that the radiance is still increasing. As the zenith angle is increased toward 90°, a point will be reached where almost all of the radiance is emitted by the lowest layer. However, if this layer is coarse enough, the increase in radiance is offset by the decrease in scattering transmittance. This qualitative description of how the dip is created is better illustrated in table 1 where the scattering transmittance, τ_s, the percentage of radiance contributed by a layer, P, and the layer temperature, T, are shown for zenith angles of 90°, 90.05°, and 90.15°

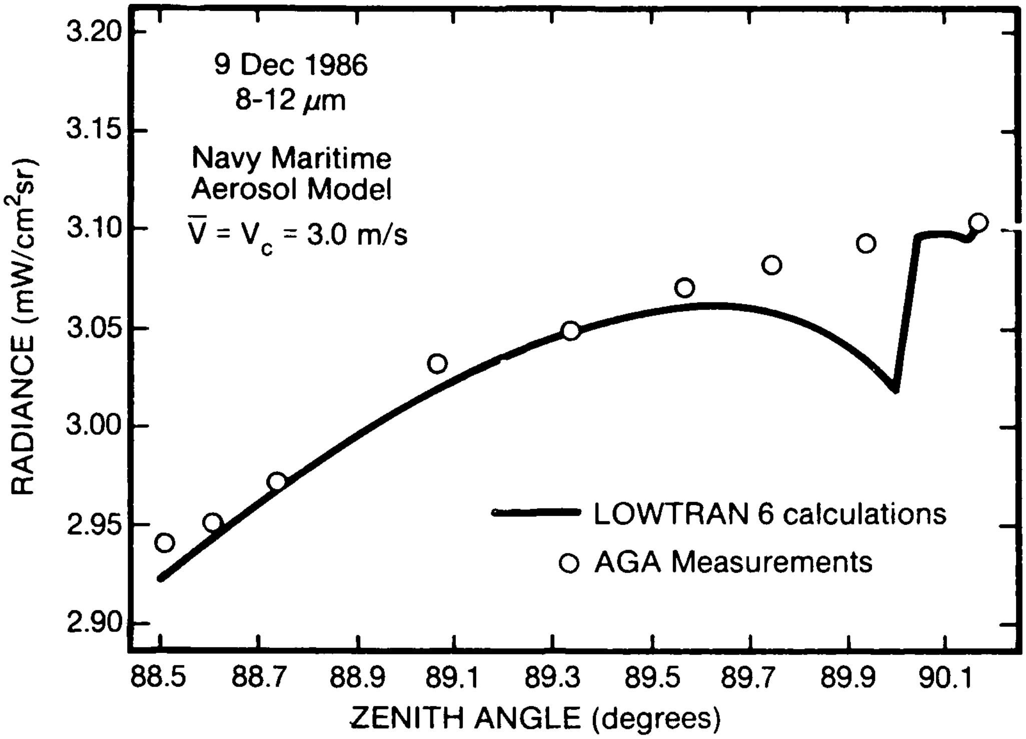

Figure 1. Comparison of measured sky radiances and those calculated by LOWTRAN 6 versus zenith angle.

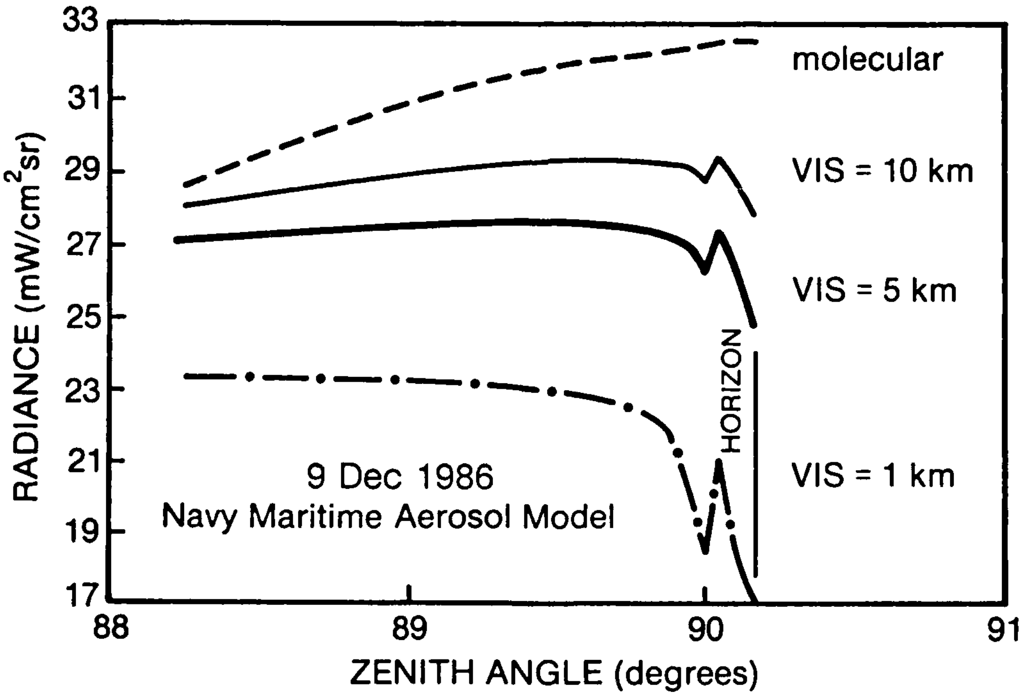

Figure 2. Radiance calculated with LOWTRAN 6 as a function of zenith angle for different aerosol concentrations (VIS = 1, 5, 10 km and molecular).

for the 9 December data. For zenith angles greater than 90°, an additional atmospheric layer is introduced between the sensor and minimum height of the optical path. About the same amount of radiance originates out of the first two layers as compared to one layer before, but the scattering transmittance is also increased.

Table 1. Scattering transmittance τ_s, percentage of layer contribution to radiance P(%), and layer temperature T(°K) for different zenith angles (θ) of 90°, 90.05°, and 90.15° and layer heights. For zenith angles of 90.05° and 90.15°, the height of 0.033 km appears twice because the ray path is first bent downwards and then upwards.

θ = 90.0°				θ = 90.05°				θ = 90.15°			
Ht (km)	τ_s	P (%)	T(°K)	Ht (km)	τ_s	P (%)	T(°K)	Ht (km)	τ_s	P (%)	T(°K)
0.033				0.033				0.033			
		95.5	289.29			80.0	289.42			98.6	289.33
0.046	0.73			0.030	0.850			0.007	0.642		
		4.4	288.71			15.7	289.42			1.3	289.33
0.088	0.524			0.033	0.725			0.033	0.412		
		<1	288.36			3.6	289.24			<0.1	289.22
0.129	0.425			0.046	0.598			0.046	0.373		
						<1.0	288.7				
				0.088	0.438						

The effect of introducing additional layers is shown in figure 3 using data acquired on 30 June 1987. The LOWTRAN 6 calculations were made using the Navy Maritime Aerosol Model with the 24-hour average and current wind speeds as shown and an air mass factor of 3. Each original radiosonde layer is divided into sublayers depending on the optical thickness of the layer. Each sublayer contains the same amount of absorbing and scattering material, and the temperature of the layers is assumed to be the same as the original layer. An advantage of this approach is that it needs no additional meteorological data. In the figure, the dip at 90° is greatly diminished, and the measured and calculated radiances agree well.

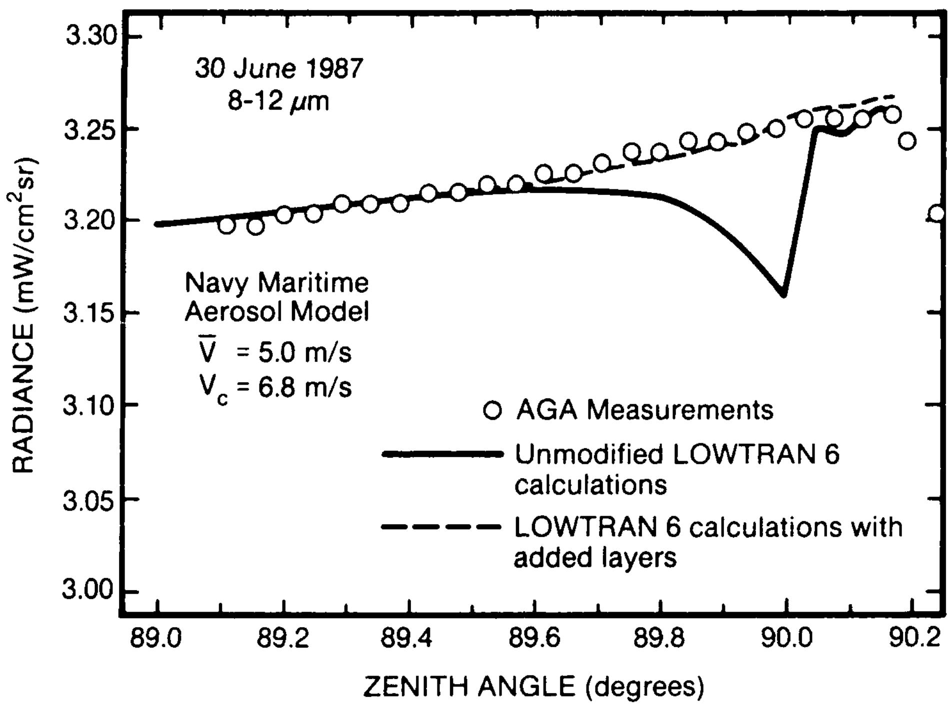

Figure 3. Comparison of measured sky radiances and those calculated by LOWTRAN 6 with and without additive layering versus zenith angle.

COMPARISON WITH A MULTIPLE SCATTERING VERSION OF LOWTRAN

Isaacs et al. (1986) recently published a new version of LOWTRAN 6 that includes multiple scattering (hereafter referred to as MS LOWTRAN) using a two-stream approximation. Figure 4 shows the radiance at a zenith angle of 90° as a function of wavelength calculated with MS LOWTRAN and LOWTRAN 6 for a midlatitude summer standard atmosphere (with layer thicknesses of 1 km within the first 25 km) and a Rural Aerosol Model (VIS = 5.0 km). The LOWTRAN 6 calculations are much lower than those for MS LOWTRAN which are in closer agreement with the measurements of Ben-Shalom et al. (1980). Superimposed on the figure are the LOWTRAN 6 radiances calculated using the single scattering, additive-layer approach. Since the multiple scattering approach simply adds radiance to the existing single scattering calculations, the resulting radiances in this instance would be placed well above the Ben-Shalom et al. (1980) measurements. This comparison raises questions as to the validity of the multiple scattering approach in the far infrared wavelength region.

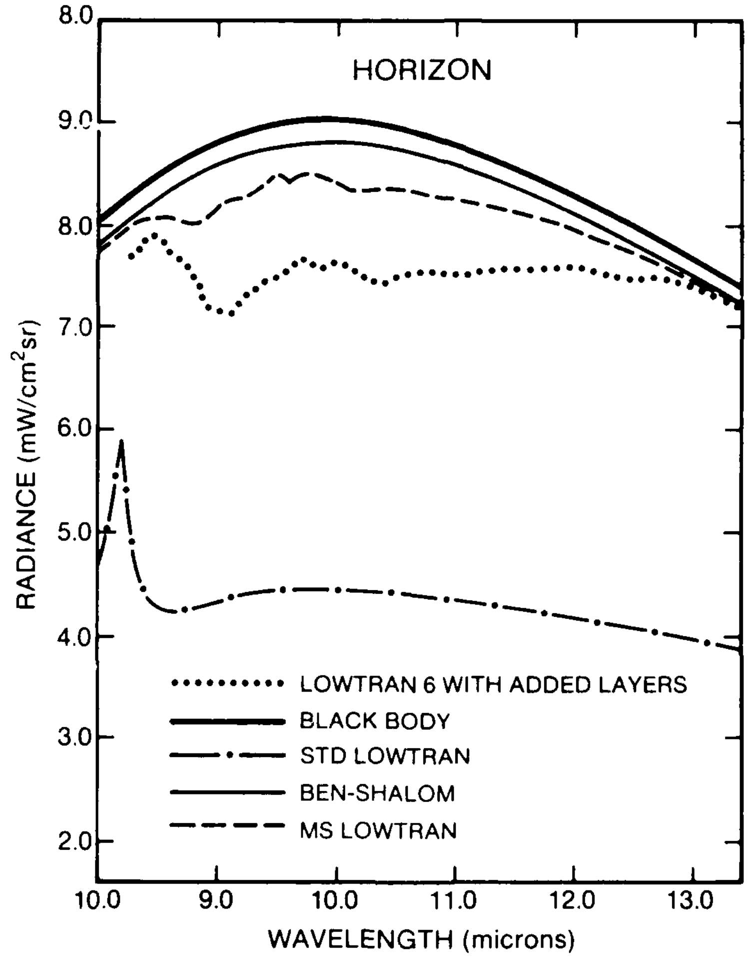

Figure 4. Comparison of sky radiances measured by Ben-Shalom et al. (1980) and those calculated by LOWTRAN 6 with and without additive layering and by MS LOWTRAN.

REFERENCES

A. Ben-Shalom, B. Barzilai, D. Cabib, A.D. Devir, S.G. Lipson, and U.P. Oppenheim. 1980. "Sky Radiance at Wavelengths Between 7 and 14 μm: Measurements, Calculations, and Comparison with LOWTRAN 4 Predictions," Appl. Opt., vol. 19, no. 6, p. 838.

H.G. Hughes, W.J. Schade, and L.R. Hitney. 1986. "Effects of Aerosols on Low-Elevation Infrared Sky Radiances," Appl. Opt., vol. 25, no. 10, p 1536.

H.G. Hughes. 1987. "Evaluation of the LOWTRAN 6 Navy Maritime Aerosol Model Using 8- to 12-μm Sky Radiances," Opt. Eng., vol. 26, no. 11, p. 1155.

R.G. Isaacs, W.C. Wang, R.D. Worsham, and S. Goldenberg. 1986. "Multiple Scattering Treatment for Use in the LOWTRAN and FASCODE Models," AFGL-TR-86-0073.

F.X. Kneizys, E.P. Shuttle, W.O. Gallery, J.H. Chetwynd, Jr., L.W. Abreu, J.E.A. Selby, S.A. Clough, and R.W. Fenn. 1983. "Atmospheric Transmittance-Radiance: Computer Code LOWTRAN 6," AFGL-TR-83-0187.

J.E.A. Selby, F.X. Kneizys, J.H. Chetwynd, Jr., and R.A. McClatchey. 1978. "Atmospheric Transmittance Radiance: Computer Code LOWTRAN 4," AFGL-TR-78-0053.

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